American Society of Cinematographers Motion Imaging Technology Council Progress Report 2017

By Curtis Clark, ASC; David Reisner, D-Cinema Consulting; David Stump, ASC; Bill Bennett, ASC; Michael McDonough, ASC, BSC; Jay Holben; Don Eklund; Bill Mandel; Michael Karagosian; Eric Rodli; Steve Schklair; Gary Demos; Jim Fancher; Gary Mandle; Greg Ciaccio; Tim Kang; Joshua Pines; David Morin; Garrett J. Smith; W. Thomas Wall

Introduction

ASC Motion Imaging Technology Council Chair: Curtis Clark, ASC

During our past 14 years of proactive motion picture and TV industry engagement, the ASC Technology Committee has played a significant leadership role in guiding the evolution and development of key motion imaging technologies to better support our filmmaking art form.

Many of our industry partners and supporters of our recommendations, along with users of our technologies, have suggested that the Committee's name does not sufficiently convey the scope and influence that our activities have had on important motion imaging technology developments. In response to that input and after careful consideration, we have decided to change the Committee's name to the **ASC Motion Imaging Technology Council**. We believe this better represents the expanded scope of the work we are doing and our widely recognized role as industry leaders - influencing the advance of motion imaging technologies in ways that best serve the creative interests of filmmakers while emphasizing the cinematographer's contribution to the art form.

Our subcommittees will now be designated **Committees** of the **ASC Motion Imaging Technology Council**. We will continue to encourage our Committees to work in a coordinated manner, combining their expertise on topics of wide interest and concern, including ACES, HDR, digital motion picture camera developments, look management, virtual production techniques, lens developments, DI, motion imaging workflows, projection and display technologies, archiving, as well as advanced imaging.

Filmmakers are currently experiencing the accelerated convergence of several key technology developments that are expanding the creative possibilities of our digital motion imaging future. Prominent among these are high dynamic range (HDR) for both TV displays and in cinema, along with wide color gamut (WCG) beyond both BT.709 and DCI P3.

The rapid advance of HDR currently being deployed for ultra-high definition (UHD) television displays, including the BT.2020 WCG target, has raised urgent questions regarding the standards-based implementations which filmmakers need to reliably support their creative intent and ensure consistent image display quality across multiple content distribution platforms. Also, the release of the Academy Color Encoding System (ACES) 1.0 has further encouraged wider industry adoption of this vital standards-based color management system and image interchange framework that supports filmmakers' use of WCG with HDR. Both WCG and HDR are crucial to the development of a new expanded creative canvas with enriched color palette. It should be noted that new development work on ACES has recently begun that will further enhance its performance throughout production and postproduction.

In addition to greater spatial resolution (4K/8K), there is growing interest in increased temporal resolution via higher frame rates beyond 24 frames/sec, up to 120 frames/sec.

I would also like to mention that important further developments are being planned for our multi-Award-winning ASC CDL (American Society of Cinematographers Color Decision List). Please see the report from our DI Committee for details.

The convergence of these advanced digital motion imaging developments requires enhanced workflow infrastructure to successfully support their implementation from shooting through post finishing. These important developments are gaining solid traction which is accelerating their adoption by filmmakers to enable greater creative potential.

Our Committees are advancing their work as reported in our 2016 ASC Technology Committee progress report. We continue to proactively engage key technology developments that are influencing our motion imaging future. In addition to high dynamic range (HDR), the latest

Digital Object Identifier 10.5594/JMI.2017.2721778
Date of publication: 18 August 2017

1545-0279/17©2017SMPTE

high resolution TV displays (both consumer and professional), cinema projection, wide color gamut (WCG), evolving Virtual Production techniques, along with the most recent digital motion picture cameras and lenses, we are further expanding the scope of our work to include Virtual Reality (VR).

The following reports from our Committees cover in detail their crucial work to address the growing array of motion imaging technology developments impacting the art of filmmaking.

The ASC Motion Imaging Technology Council is guided by its primary mission to engage and influence motion imaging technology developments in ways that better serve and protect the filmmaker's creative intent and the role of the cinematographer in realizing a creative vision that best serves that creative intent.

I would like to thank all those who generously devote their time and expertise to support the mission of the ASC Motion Imaging Technology Council.

Secretary's Comment

ASC Motion Imaging Technology Council
Secretary: David Reisner, dreisner@d-cinema.us

As we have learned in many areas of our world and our work, when an activity or technology has moved into the digital realm, development and change happen both quickly and continuously.

In the last couple of years, digital cinema cameras have reached feature motion picture levels of performance, and we have seen several cameras gain wide, popular use and acceptance. I had thought the pace of camera development and release would slow, but exactly the opposite has been true. The past year has shown a surge in release of new cameras, all the way from high-end personal video cameras thru high-end feature motion picture cameras from multiple manufacturers. See our Camera Committee report for a deeper dig.

It is, as ever, the artist's job to identify the right camera, with the right set of characteristics, for the individual movie or show, which gives us the happy responsibility of doing show-specific testing. With things like ACES in the workflow, camera-to-camera consistency has significantly improved for digital cameras, but I still strongly advocate scene-to-screen testing before selecting equipment and starting a project (which ultimately improves results, saves money, and protects schedule). (HBO's Camera Assessment Series 2017 (their 5th season) does their best job yet giving insight into camera characteristics. A viewing on your target medium – HDTV (High-Definition Television), UHDTV (Ultra-High-Definition Television), or cinema – should definitely be on your list.)

After years of work, study, and comment by rental houses, the Academy Sci-Tech Council, the Academy Scientific and Technical Awards Committee, the ASC Motion Imaging Technology Council Camera Committee, and others, this year camera vendors have seemed to become fully awake to the critical role of IR (Infra-Red) filters in digital imagers. This is an important change as the relationship between IR filters and digital imagers is an intimate one, and camera manufacturers are in by far the best position to address the issue.

High Dynamic Range displays can provide an immediately compelling image, and the value of that attractiveness has not been lost on consumer electronics manufacturers. The majority of UHDTVs (the current generation of consumer TVs) are HDR-capable, but the characteristics vary meaningfully from product to product – both minimum and peak brightness (peak usually different for small and large fields) and the mapping from input signal to displayed image. These variations make it challenging to consistently deliver artistic intent to the viewer. For several years, the ASC Motion Imaging Technology Council has been working with studios and manufactures to try and improve this situation, but the problem is quite complicated in both absolute and practical technical terms and with the multiple business interests including manufactures, content providers, and broadcasters. (In this case, OTT providers are the easiest part and often strongest allies.) From the business+viewer side, see our UHDTV Committee report. To really understand the technical and artistic intent issues, and to appreciate part of the massive problem of the need for many masters and distribution versions, I strongly commend both this and last year's Advanced Imaging Committee reports.

While, so far, High Dynamic Range is mostly deployed in the home, there is certainly interest in HDR presentation in the theater. Dolby is making strong efforts with their DolbyVision theaters, IMAX has their own high-quality and High Dynamic Range theaters, and DCI (Digital Cinema Initiatives) has recently approved Samsung's new and nicely designed, large, modular Cinema Screen emissive display for use in D-Cinema theaters. See our Next Generation Cinema Display Committee report for more on theatrical displays.

Artificial Intelligence (AI) and Machine Learning (particularly Deep Learning) are terms and technologies that are already changing our world. I did work in those areas in the early-1980s and originated Pervasive Computing (a more sophisticated forebearer of the currently popular IoT - Internet of Things), and I predict that the effect of those changes will fundamentally reshape what we consider normal and expected. Think of the fundamental changes in behaviour and expectations caused by cell phones / smart phones, and magnify and apply across even wider areas of human activity.

How that will manifest in entertainment imaging is still a matter of speculation and experiment, but a near-term need is finding ways to deliver artistic intent to viewers across a wide range of devices with very different characteristics, without having to create a large number of masters by-hand. Cloud infrastructure, massive data communication, and computational resources made available by the work of companies like Google, Amazon, Nvidia, and many others, and large scale customers including Netflix, Amazon, and other OTT providers will give the opportunity for that development and deployment. Massive technology serving the goal of delivering artistic intent to the broadest range of viewers.

Another element of the world's digital transition will surely be Computational Imaging – various methods of collecting a lot of light information and then using computation to form that into images for a specific purpose. We will certainly see computational imaging used widely – perhaps universally – in devices like cell phones. While movie-making is enjoying and benefiting from the continued development of "traditional" cameras, the scale and cloud-accessibility of computational resources will continue to make Computational Imaging a possible component of our movie-making world. Although there remains significant technological development to be done in Computational Imaging, our biggest issues will be aesthetic – how or if to use it to tell stories compellingly – and business – how to manage a production and its budget so that cinematographers, the artists of imaging, are involved at all the points in the process where the image is shaped – in production and now in the vastly expanded image shaping of post-production where a cinematographer's artistry and involvement will be completely essential.

The surge in Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Although when well done, VR is obviously compelling, we don't yet know how it will function for long-form entertainment. Humans have told stories to other humans for as long as we have been around, but listening to stories is still almost entirely a sit-back activity. We don't know if sit-forward story telling will yield a compelling experience, regardless of the balance of production cost and audience. From an entirely different angle on story telling, the video game market remains huge (perhaps $75B/year vs. movie industry $35B/year (Wall Street Journal)). Aside from entertainment and market size, I continue to predict that AR (or perhaps what is now sometimes called MR) will make huge and important differences in our world – computer analysis and assistance for a surgeon or aircraft engine repair engineer being traditional examples. For a good look at actual current activity, see the reports from our Joint Technology Committee on Virtual Reality and Joint Technology Committee on Virtual Production. The Virtual Reality Committee is developing a project to produce a short virtual reality narrative.

So, the ASC Motion Imaging Technology Council should have enough to keep us busy for awhile…

The ASC was formed 98 years ago to help industry experts work together as a team to produce exceptional imaging and tell exceptional stories. The modern ASC actively continues that tradition through the every-day work of its Members, Associates, and staff.

Camera Committee

Chair: David Stump, ASC
Vice-Chair: Richard Edlund, ASC
Vice-Chair: Bill Bennett, ASC

The ASC Motion Imaging Technology Council Camera Committee engaged in a number of community activities this year.

Metadata

The interest kindled in the last few years at numerous camera manufacturers, lens companies and software companies is moving forward in renewed effort to unify metadata standards in cinematography, especially lens data for inclusion in image files. Zeiss have very recently introduced their new ZEISS CP.3 Compact Prime lenses with eXtended Data that tracks focus information, lens distortion and shading characteristic information in realtime for every frame. That metadata is either recorded to the camera data stream or to an Ambient MasterLockitPlus. The Compact Primes provide the metadata included into DPX files or RAW files via either system, depending on the camera set up, and some grading tools are now giving users the ability to de-warp and control lens shading on set. The lenses are compatible with the Cooke I system, and provide a glimpse into the future of automated realtime on set metadata collection.

Emerging Camera Technology

At the beginning of 2016 the Camera Committee received a request to evaluate a new prototype camera technology: the Lytro light field cinema camera. As a matter of personal interest, I have been following development of Light Field capture and plenoptic computational imaging via the research papers on the topic that first came out of Stanford University, so after discussions with the Lytro Camera Company, the Virtual Reality Company (VRC) and Curtis Clark, ASC, I agreed to work as DP for director Robert Stromberg to shoot a short test film with the Lytro Cinema prototype camera.

The short film "Life" was developed and designed by Robert, and shots were defined together with Lytro's Executive Producer, Jeff Barnes, to produce a test that could demonstrate capabilities of the technology.

The success of the debut of the camera and the short film led to the development of a second generation light filed camera at Lytro, and I hope to be taking their second generation light field camera onto a real world production later this year.

Additionally, the Camera Committee has been tracking the development and introduction of several new cameras for digital cinema.

ARRI

Alexa SXT, using the same sensor as previous versions of the Alexa, has the ability to record in-camera UHD ProRes or DCI 4K ProRes, both are upscaled resolutions, as the sensor is 3.4k. Can record ProRes to SxS cards or CFast cards, and ArriRaw to Codex XR 512Gb, or SXR 1 or 2 TB drives. Max frame rates recording RAW: 120 frames/sec in 16:9, 90 frames/sec in Open Gate 3.4k

Blackmagic Design

URSA Mini Pro 4.6K - has a switchable lens mount: EF, PL, and B4, with the B4 lenses shooting a windowed HD mode. With a S35 sensor, it records to SD or CFast cards, in CinemaDNG RAW or ProRes formats, at up to 60 frames/sec in 4.6k RAW.

Canon

C700 - S35 4K recording at 60p to CFast 2.0 cards using the XF-AVC format. With the addition of a module, it can record RAW data at 4k, 120 frames/sec to Codex solid state drives.

Panasonic

Cinema VariCam Pure - S35 4K/2K camera system, dual ISO 800/5000, and built-in, uncompressed RAW up to 120 frames/sec, utilizing Codex solid state drives.

Panavision

Millennium DXL - VistaVision size sensor derived from the Red Epic W VistaVision, 8k resolution, 60 frames/sec max at 8k full frame, 75 frames/sec at 8k 2.41:1, Recording format Red RAW with simultaneous 4K proxy (ProRes or DNx), Light Iron Color, 5 different series of Panavision large format lenses, spherical as well as anamorphic.

RED Digital Cinema

Red Epic-W and Weapon 8K S35 - both with "Helium" 8k Super-35 sensors, and the addition of ProRes and DNXhd recording codecs, in addition to Red Raw, join the DSMC2 family of cameras. The Weapon 8K S35 can shoot a maximum of 60 frames/sec at 8k resolution. Red says that the current camera form factor will remain until at least 2020.

Sony

Sony showed many of their new developments including upgrades to their F55, a new R7 recorder module that does 120 frames/sec 4K compressed raw, 2 new more efficient codecs, and XOCN (Extended Original Camera Negative).

Eastman Kodak

Yes, film… Kodak announced the opening of a film labs in London and New York City to process negative, and provide film scanning services. Number of movies shot on film: 39 in 2014, ~64 in 2015, ~29 in 2016. The winner of the 2017 Academy Award for Best Cinematography, "La La Land" was shot on 35mm film.

Other Technologies

High Frame Rate acquisition and post processing. RealD TrueMotion

This technique was used by Ang Lee and John Toll, ASC to create the 24 frames/sec and 60 frames/sec release versions of "Billy Lynn's Long Halftime Walk". Bill Bennett, ASC also used this technique to shoot shot a demonstration piece titled "Flamenco" for RealD.

The technique is to shoot digitally with 360° shutter at 120 frames/sec or higher. Then post-process the images with RealD TrueMotion™ synthetic shutter software for any frame rate output (e.g., standard 24, or any high frame rate). The color and metadata are untouched during this process. During the process you select the synthetic shutter to render the motion look best suited to your scene. The process can eliminate judder in fast moving silhouetted objects moving against bright backgrounds in HDR displays. There is the option to control the speed of apparent motion (simulate over- and under-cranking), create a speed ramp in a sequence, with a simulated constant shutter angle throughout the speed change. You then output at the selected framerate, and the output images ready to pass into existing editing and post production workflows. The process works with ProRes, H.264, ARRIRAW, ACES (EXR), DPX, and TIFF original file types. The output format is the same as the input format, with the color, contrast, latitude, metadata, etc. unchanged.

High Dynamic Range Capture and Finishing

In January, Dave Stump ASC went to Beijing China to workshop the techniques of capture and DI finishing of High Dynamic Range Images for CCTV, the state run Chinese Television network. A week of training in both acquisition and post workflows provided a head start to Producers, Directors, Cinematographers and Colorists as CCTV embarks on opening an HDR channel for China.

Lens Committee

Co-chair: Michael McDonough, ASC, BSC
Co-chair: Jay Holben

The Lens Committee was formed in the fall of 2016 with Michael McDonough, ASC, BSC as its chair. Early members included Bill Bennett, ASC; Seth Emmons of Leica; Tom Fletcher; Jay Holben; Chuck Lee of Fujifilm Optical Division; Snehal Patel of Zeiss Camera Lens

Division; Kish Sadhvani of StarKish Enterprises; and Dan Sasaki, VP of Optical Engineering, Panavision. The Committee's first official meeting was held on September 29 with a primary focus set to solidify its mission statement:

The Lens Committee of the American Society of Cinematographers is formed under the umbrella of the ASC Motion Imaging Technology Council and endeavors to:

- Further progress the artistic capabilities and expression of Cinematographers with respect to lenses and optical accessories;
- Educate and inform our fellow Motion Imaging Technology Council Committees, ASC members, members of fellow societies, Cinematographers around the world, creatives, manufacturers and the public on the history, technology and creative applications of the wealth of lenses from our past, present and future;
- Become a forum for the exchange of ideas between cinematographers, ASC Motion Imaging Technology Council Committees and lens manufacturers;
- Formulate and encourage the development of industry-wide standards that all manufacturers can embrace.

In these four objectives we strive to foster new dialogue between lens professionals on all sides of the optical equation from manufacturer to end user.

At the first meeting, McDonough nominated producer/director, former cinematographer and long-time contributor to *American Cinematographer* magazine, Jay Holben, as the co-chair of the committee and the motion was quickly passed. The Committee has also rapidly grown to nearly fifty members including representatives from Arri, Anegnieux, Camtec, Canon, Clairmont, Cooke, Duclos, Fujifilm, Keslow, Leica, Panavision, Red and Zeiss in addition to some of today's top optical engineers like Iain Neil and cinematographers like Bill Bennett, ASC; Matty Libatique, ASC; Nancy Schreiber, ASC; Markus Foerderer, BVK; and others.

Since the inaugural meeting, the duo-chairs have led the committee through a trio of bi-monthly meetings and set out several ambitious projects for the Committee to tackle.

Comprehensive Cine Lens Database

One of the first projects that the Committee has undertaken is the Comprehensive Cine Lens Database (CCLDb). Originally started by Holben and Christopher Probst, cinematographer and technical editor for *American Cinematographer* magazine, for the 9th Edition of the *American Cinematographer Manual* (2004), Holben and Probst set out in early 2015 to expand and update the approximately 1,000 lenses listed in the manual and expand each entry with more technical information.

Close Focus (m)	Close Focus (1 in")	Close Focus (f decimal)	Illumination Circle (mm)	Year / Decode	Country of Origin	Iris	# elements	# groups	# aspherics
0.20	8"	0.67	43.3	2013	Japan	11			
0.36	12"	1.17	43.3	2012	Japan	11			
0.36	12"	1.17	43.3	2012	Japan	11			
0.46	1'6"	1.5	43.3	2012	Japan	11			
0.97	3'2"	3.17	43.3	2012	Japan	11			
0.99	3'3"	3.25	43.3	2013	Japan	11			
0.30	1'	1	43.3	1982	Japan	15	12	9	1
0.30	1'	1	43.3	1982	Japan	15	10	8	1
0.30	1'	1	43.3	1982	Japan	15			
0.46	1'6"	1.5	43.3	1982	Japan	15	8	6	1
0.91	3'	3	43.3	1982	Japan	15	8	6	1
0.30	1'	1	43.3	1978	Japan	15	12	9	1
0.30	1'	1	43.3	1976	Japan	15	10	8	1
0.30	1'	1	43.3	1976	Japan	15			
0.46	1'6"	1.5	43.3	1976	Japan	15	8	6	1
0.91	3'	3	43.3	1976	Japan	15	8	6	1
0.30	1'	1	43.3	1977	Japan	15			
0.30	1'	1	43.3	1973	Japan	15	10	8	1
0.30	1'	1	43.3	1974	Japan	15			1
0.46	1'6"	1.5	43.3	1973	Japan	15	8	6	1
0.91	3'	3	43.3	1975	Japan	15	8	6	1

FIGURE 1. A sample of a small section of the database and information collected within. In this section, representing Canon cine lenses, the database not only lists the modern CN-E Cinema Primes, but the 1970s vintage K35s as well - also making sure to detail the versions of K35s including the first release which included thoriated glass.

They spent more than eighteen months laboriously researching the wealth of cine-style optics in the marketplace before bringing the project to the newly-formed Lens Committee and proposing a joint-project. Once embraced by the Committee, the database was divided up among the manufacturers who were represented on the committee for verification and additional information. The database currently lists more than 2,400 cine-style optics along with as much technical information can be gathered for each lens: Manufacturer; Original format designed for; Type (Prime or Zoom or Specialty); Shape (Spherical or Anamorphic); Special identifiers: family name, model number, genealogy, attributes; Focal length; *f* or T stop calibration; Maximum aperture; Minimum aperture; Close focus distance (MOD) (imperial & metric); Manufacturer stated image circle; Year/decade of introduction; Country of origin; Number of iris blades; Number of glass elements; Number of glass groups; Number of aspherical lenses; Number of

Focus Mechanism	Focus Rotation	Iris Rotation	Zoom Rotation	Front diameter (mm)	Front Filter Thread (mm)	Length (Inches)	Weight (1b)	MOUNT PL	MOUNT Panavision	MOUNT Mitchell NC/BNCR
	300	36	N/A	114		3.7	2.6	PL		
	300	36	N/A	114		4.0	2.65	PL		
	300	36	N/A	114		4.0	2.43	PL		
	300	36	N/A	114		4.0	2.43	PL		
	300	36	N/A	114		4.0	2.87	PL		
	300	36	N/A	114		4.6	3	PL		
Helical			N/A	110				PL		BNCR
Helical			N/A	80				PL		BNCR
Helical			N/A	80				PL		BNCR
Helical			N/A	80				PL		BNCR
Helical			N/A	80				PL		BNCR
Helical			N/A	110						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR
Helical			N/A	80						BNCR

FIGURE 2. The database strives to catalog as much information as possible that might be pertinent to an individual cinematographer. This includes not only minimum object distance (close focus), but the year and country of origin of the lens, which informs many aspects of its character. When possible the database goes as far as to catalog the number of elements, aspherical elements and exotic glass elements.

exotic glass elements; Type of focus mechanism (cam or helical); Focus rotation; Iris rotation; Zoom rotation; Front diameter; Front filter thread diameter; Length (imperial & metric); Weight (imperial & metric); Any mounts available for the lens; Intelligent electronics; Lists of films shot; and any special notes. It is a wealth of information, much of which cannot be easily found elsewhere.

With the number of camera manufactures steering away from Super35-sized digital sensors towards larger ones, the question often arises, 'Will this particular lens cover my large sensor?' The CCLDb makes great strides towards answering this question in a meaningful manner. First with the inclusion of the extremely important 'Manufacturer stated image circle' measurement information. This is, according to the manufacturer's own terms, the image circle that the lens is intended to be used for.

The issue of image circle becomes increasingly complex, however. To answer the deceptively simple question, 'Will this particular lens cover my large sensor?' one must break the query into several levels. The first level of the answer has to come from: is there *any* image projected from the lens that will cover the entire rectangle of the image sensor in question. In other words, is there a large enough circle of illumination from the lens to provide an image all the way across the sensor without black port-holing?

The next level to the question is: *how much* illumination is there to cover the edges of the larger sensor? Most lenses have 'extra covering power,' that is an area of the image circle, beyond the manufacturer-designated circle of good definition, where there is still illumination, albeit that the falloff or vignetting may darken that area. How much darkening at the edges, compared to the center of the lens, is acceptable is completely up to the individual aesthetics of the cinematographer and demands of a particular project or client. Additionally, the isotropic sampling structure of digital sensors tend to accentuate oblique angles of light and make the vignetting of a particular lens more exaggerated than would be seen with the more organic, anisotropic sampling of film emulsion. Further, the performance of any lens in resolving power, contrast and aberration control, diminishes as the image approaches the fringe of the optics. It is highly possible that there may be sufficient illumination at the edges of the extra covering power to cover a larger sensor, but that the performance of the lens may degrade substantially in this bonus area. How to adequately measure and quantify the amount of extra covering power and what might be acceptable for any given cinematographer or project demands is a herculean effort.

Enter Duclos Lenses. Matt Duclos, son of optomechanical engineer Paul Duclos, is an active member of the Committee. The Duclos company has been embarking on a similar project with their Image Circle Evaluation Box (ICE Box), a tool to visually record the full image circle (circle of good definition and extra covering power) from any lens at every marked focal distance, aperture and zoom focal length (if applicable). The result is a visual depiction of the circle of illumination with superimposed reticles for any available camera sensor size and a small guide to indicate the diameter measurement of the circle of illumination. It is then left to the cinematographer to determine if, based upon this visual information, the lens will be appropriate for them to specifically test for their needs. This visual database will be directly linked to the ASC Comprehensive Cine Lens Database so that cinematographers may look up any lens that is cataloged with the system and learn about its full illumination circle attributes.

As the digital cinema camera technology overtook film technology for the primary origination methodology of motion pictures, more and more cinematographers began shying away from modern high-end, sharp, contrasty and high-resolution lenses for older, softer, less contrasty, less resolving-power lenses that helped the digital images feel more 'filmic.' This led to a resurgence of 'vintage' cinema optics that had, literally, been gathering dust in the deep, dark corners of rental houses for decades – some were only used as paperweights and doorstops. Unfortunately these delicate, older lenses cannot necessarily withstand the rigors of modern production with lens motors, high g-force camera operation and often punishing conditions of extreme weather. The CCLDb strives to catalog not only the original, vintage, lenses, but those that have been rehoused to be better suited to modern motion picture production.

Some of the more esoteric bits of technical information cataloged in the CCLDb may not be available for all lenses. For instance, not every manufacturer readily offers the number of glass elements, groups, aspherical surfaces and/or exotic glass elements in their products. To some cinematographers, however, this is pertinent and valuable information. A common theory regarding the three-dimensionality perspective of lenses, those which present the world with more depth cues, surrounds the number of glass elements in the lens. The fewer the elements, the more dimensionality a lens has. The more elements, the more flat the lens' perspective may be. Although actual optical design theory proves this concept to only be *somewhat* valid, there are some cinematographers who seek out optics based, primarily, on their number of elements. For a cinematographer looking for a high-performing, low-aberrant lens, information on the number of aspherical surfaces and exotic glass elements is very key to their decision making. As noted earlier, not every lens will have this particular information listed for it, but the Committee endeavors to make it available for as many of the lenses in the database as possible.

The ambitious goal of the CCLDb is to offer detailed technical data for any cinema-style lens that has ever been used on a film camera in the history of motion picture production.

The Database will live on the ASC website and be a free service to the community and will continue to be updated and refined on a constant basis.

Smart Lens Metadata

The second project undertaken by the Committee is the investigation into recommending standards regarding Smart Lens Metadata, the procurement of it, and the protocol by which it is presented to camera systems and carried on to post-production software tools.

The two prevailing systems in today's cinema marketplace are the ARRI LDS (Lens Data System) and the Cooke /i system. The Committee is examining both systems to determine which might serve as a better industry-wide standard, if not a combination of both.

Beyond a standard for the metadata at the lens side, there exists a serious need to coordinate with camera manufacturers to more openly adopt this metadata as part of their image files and to further coordinate with software engineers creating the post-production tools that will process and utilize this metadata. Far too often the data exists, is recorded and then lost somewhere in the production/post-production workflow and never reaches the artists who need it. The Committee will work to serve as a liaison between the lens manufacturers, camera manufacturers, software engineers and end users to refine and standardize the optical metadata pipeline to aid in its incorporation into today's visual effects-laden productions.

Currently, standard metadata includes: focus distance, aperture setting and zoom focal length, near and far focus ranges of depth of field and hyperfocal distance. Additional fields can be added and the new Zeiss CP.3 lenses utilize this additional data to incorporate dynamic vignetting and distortion information. The Cooke /i[3] system is set to include this information as a standard, in addition to other mappable lens characteristics such as chromatic aberration. With the right software platform this feature allows visual effects artists to remove

FIGURE 4. A shot of a new Zeiss CP.3 xD 50mm T2.1, the follow up to the incredibly popular Zeiss CP.2 line. The xD version of the CP.3 is the "Extended Data" incorporating the Cooke /i metadata system and incorporating open data cells to include lens-specific distortion and vignetting data that can be dialed out in post with the literal toggle of a menu option. The evolution of smart lens metadata leads us to a day when visual effects artists no longer have to shoot distortion and shading tests for every lens used on a job. Zeiss has made that obsolete with the CP.3 internal data.

FIGURE 3. A look inside a Zeiss CP.2 21mm T2.9 cine lens. This actual lens, sliced on a bandsaw, exposes the intricacies of modern optical and optomechanical design.

FIGURE 5. An inside look at the circuit board behind the Cooke /i smart lens metadata. A series of sensor resistance elements detect focus, iris and zoom ring positions and that information is processed through the internal circuitry and passed along to the camera.

FIGURE 6. PL Mount i-connectors: The four connection points (gold spherical contacts) on the back of a Cook /i smart lens. They are, from left to right, power, data and power, data to the lens and data from the lens. The external interface operates at RS232 levels with standard communication in 8 bit data without parity, 1 stop bit, in ACSII format.

the shading and distortion at the literal touch of a button. There is no longer a need to shoot distortion charts and map the lens' natural fall off. This technology, when more widely adopted, will simplify the technical aspects of visual effects lens interpretation and eliminate the need for tedious testing of every lens' individual characteristics.

Spherical Lens Day

At the behest of ASC President Kees Van Oostrum, ASC, the Committee undertook the organization of a Spherical Lens Day on June 10th, 2017 at the American Society of Cinematographers clubhouse in Hollywood. The event was open to all active and associate members of the society and featured a mini trade-show environment where the major cine-optical manufacturers showcased their products for the ASC cinematographers present to experiment with and analyze. Included were Angenieux, ARRI, Canon, Cooke, Fujifilm, Leica, Panavision, Vantage and Zeiss. An interior "set" was lit with live models to test many facets of the lenses contrast, resolution, sharpness, skintone reproduction, perspective, color fidelity, bokeh and flare characteristics. A second, exterior set, focused on the same parameters for large format cameras - namely the Arri Alexa 65 and the Panavision DXL.

In addition, the Committee invited the top lens rehousing companies: True Lens Service, GL Optics and P+S Technik to show their wares to the cinematographers. These companies are helping to revive old, lost lenses that have been gathering dust or fallen into terrible states of disrepair. Reinvigorating them with new, modern, optomechanical design, more robust housings, standardized sizes, gears and smooth operation – true vintage lenses like Bausch and Lomb Super Baltars, Kowa Prominars and larger image circle still lenses like Leica R and Hasselblad lenses are now available for use in the cinematography world and can seamlessly integrate into today's production demands.

The Future

Recently, additional topics have been brought to the Committee co-chairs for consideration: a look at standardizing how lens focus witness marks are calibrated and engraved, and a look at a system of calibrating and quantifying the effects of various lens diffusion filters. Both topics will be discussed and evaluated as possible future projects at the next Committee meeting. Another lofty project proposes the concept of tracking specific lenses, by serial number, to some of the most influential films in cinema history and being able to attribute a specific physical lens to a specific use by a great cinematographer in cinema mythos.

Finally, one goal of the Committee is to help to educate the other Motion Imaging Technology Council Committees and the cinematography community, as a whole, on various aspects of lenses, optical design, lens characteristics and so forth. No formal decisions are yet made as to which topics will be first covered by the Committee but some candidates are: measuring lens resolving power against today's digital sensor resolutions; understanding the out of focus image, what makes up the lens bokeh; the pitfalls of utilizing lenses designed for film on today's digital sensors, and more.

UHDTV Committee

Chair: Don Eklund
Vice-Chair: Bill Mandel
2nd Vice-Chair: David Reisner

2016 ended with activity around HDR continuing to ramp up. 2017 may become a pivotal year in the transition from HD 1920x1080 television to UHD "4K" 3840x2160 HDR television. The ITU completed the BT.2100 specification in July of 2016 documenting two baseband systems, one based on the Perceptual Quantizer (PQ) transfer function, the other on Hybrid Log Gamma (HLG). Interest in HDR has widened across the motion picture and television industries, with a strong showing of HDR technology at CES and

FIGURE 7. Side by side demonstration of both BT.2100 HDR systems - PQ and HLG.

FIGURE 8. HDR reference image shoot (April 2017).

NAB. Distribution of HDR content has broadened with many titles available in UHD HDR on the Ultra HD Blu-ray format. Distribution outlets and OTT providers like Amazon and Netflix are producing outstanding examples of HDR programming with original series programs that show how compelling images that use the combination of resolution, dynamic range, color and frame rate can be.

Several organizations continue to influence the growth and adoption of UHD. The UHD Alliance has been certifying premium televisions to their standards. The UHD Forum has been producing HDR production and workflow guideline documents and both organizations continue to work on ensuring quality end user experiences

Since our last report, the Committee has continued its work to explore HDR technologies in distribution and capture and is working alongside other ASC Motion Imaging Technology Council Committees on Advanced Imaging, Digital Display, and Next Generation Cinema Display as interest in HDR expands. Filmmakers are showing an increased understanding of the implications between brightness and dynamic range as they make use of expanded capabilities to support their aesthetic choices for narrative storytelling. Over the last several years, the Committee has put substantial effort into exploring color grading and other tools which are essential for working with the HDR canvas. For instance, we have clearly seen that a properly calibrated and set up monitor is **required** to evaluate how these decisions are being realized.

In August 2016 the UHD Alliance solicited the assistance of the ASC, Blackmagic, Colorfront, Dolby Laboratories, Sony, and Universal to provide a side by side demonstration of both BT.2100 HDR systems - PQ and HLG - for the technical committee meeting.

With thanks to Dolby and Sony for providing two Pulsar and two BVM-X300 monitors, and the ASC for the use of the ICAS 4K HDR content, an interesting demonstration of format interchange and feature comparison of these baseband systems was made possible. This demonstration focused on the bridge point of 1000 cd/m^2 (aka nits) now described in ITU technical report on HDR and also showed how the systems behave above and below that point.

In April 2017 an HDR reference image shoot was performed at Sony Pictures on Stage 7 for the purpose of creating high quality reference images and video. The elements of the shoot included test charts, stained glass, a suit of armor, models and various lighting set-ups available in Stage 7. Cameras used included Sony and Fuji still cameras, a Sony F65, and an Arri Alexa. The time and contributions from many experts, including ASC Cinematographer Robert Primes, Sony, Arri and other members were highly appreciated. Through this effort, images were produced using a variety of cameras for the purpose of exploring the limits of HDR capture and providing additional reference footage to the industry.

As we explore the range of devices and software that are enabling advances in image reproduction, the Committee continues to consider the preservation of filmmaker creative intent to be our first priority

The Committee plans to continue work in several areas:

- Industry collaboration through testing, discussion and demonstrations
- Interoperability issues between devices and displays
- P3 color reproduction carried in BT.2020 color space with and without the use of metadata
- Reference image creation and distribution to outside organizations
- Evaluation of continually evolving display technologies and how they perform with multiple content types.

As the HDR display market expands, our Committee will look for additional opportunities to provide a bridge between the creative and consumer technologies.

Input to the group is welcome, provided that it can be shared on a non-confidential basis. Contact asc-uhdtv@d-cinema.us.

Next Generation Cinema Display Committee

Co-Chair: Michael Karagosian
Co-Chair: Eric Rodli
Co-Chair: Steve Schklair

The Next Generation Cinema Display Committee is concerned with satisfying the creative intent of filmmakers as new projection and display technologies emerge in cinema. The Committee has over 100 members, representing all major projection technology providers, the major studios, and the creative and technology leaders within the motion picture community, not just in the U.S. but around the world. Our goal is to provide expert review and guidance in the aesthetics and presentation quality of the cinematic image.

Advancements in display technologies hold great promise in materially improving the theatrical experience, but can introduce problems in post-production, distribution, and exhibition. As one example, standard cinema operates with a minimum color gamut defined in SMPTE RP431-2, more commonly known as "DCI P3." Newer projection and display technologies exhibit wider color gamut. But a wider minimum color gamut that can safely be used in post-production and distribution, at the time of this writing, still remains to be defined. Similarly, the ability of next generation projectors and displays to generate very high peak whites will become an important parameter as HDR emerges in cinema.

Technology can introduce new challenges. RGB laser projectors to date have met the demand for more light and wider color gamut, but reports of speckle and metameric variability persist. Solutions for speckle include the methods of angle diversity, polarization diversity, and wavelength diversity, but of these methods, only wavelength diversity will also reduce metameric issues. In addition, projectors can be limited in peak light output for HDR. To improve dynamic range, projectors with increased contrast are now available. Further improvements in projector peak luminance and contrast could materialize in the coming years based on technologies under development.

It is possible to achieve HDR, however, without a projector, using direct LED displays. One company, Samsung, has produced such a display for cinema, receiving the DCI compliance rating for its "Cinema Display" product in May. The display demonstrated at Cinemacon 2017 was 10m wide, with 4K resolution, a color gamut wider than P3, and the ability to display peak whites of 500 nits. Technologies such as this could herald the emergence of HDR in cinema.

As HDR finds its way into cinemas, it is unlikely that the footprint will be uniform in display characteristics. It is well-known, for example, that 3D distributions are tailored to multiple luminance levels, driven by limitations found in cinemas. HDR distributions could face a similar situation. The ASC would like to get in front of this by determining meaningful HDR peak white levels, for example. To guide the evaluation of such levels, this Committee published the "Cinema Display Evaluation Plan & Test Protocol", online at https://bit.ly/cinema-evaluation-plan.

Other fundamental work is also needed with frame rate for cinema HDR. Standard cinema productions are shot at 24 frames/sec. However, several studies demonstrate that judder is exposed in 24 frames/sec motion pictures with high peak luminance. If cinema is going to move to higher frame rates to accommodate HDR, it would make sense to synchronize with the UHD standards to eliminate conversion artifacts and simplify workflows. But the artistic requirements for cinema could differ from home, which calls for an evaluation of frame rates for HDR cinema.

HDR cinema is not merely brighter images, or images with higher contrast, but is best thought of as a completely new cinema format for storytelling. To nurture the format's success requires a careful evaluation of the parameters that determine artistic value and guide products and installations. To conduct this work requires a collection of appropriate and varied artistic content. At the time of this writing, an evaluation is underway to review available materials. It is also important to extend this study beyond experts in the Hollywood community and into Europe and China. The ASC Motion Imaging Technology Council has reached out to partners in both regions for this purpose.

Advanced Imaging Committee

Chair: Gary Demos
Vice-Chair: Jim Fancher
Vice-Chair: Bill Mandel
Secretary: David Reisner

The gamut of most displays and projectors is defined by the meaning of Red, Green, and Blue wherein only one of the three primaries is nonzero. Typically this has been defined using "chromaticity" coordinates, x,y, which are specified using CIE 1931 color matching functions (CMFs). In addition, the "chromaticity" of neutral is defined for Red, Green, and Blue all being nonzero and equal. In television systems, historically this neutral has been D65 chromaticity, again defined using CIE 1931 CMFs. However, SMPTE defined a D-Cinema "Whitepoint Gamut" wherein 14fl (= 48cd/m^2 = 48 nits) brightness can be achieved over a range of whitepoints including D55, D60, and D65.

D-Cinema has been defined as gamma 2.6 using XYZ "tristimulus" values, which add brightness to chromaticity (using 14fl as maximum). XYZ "tristimulus" values are direct amounts of light integrated with CIE 1931 CMFs. Chromaticities are defined as x = X / (X+Y+Z) and y = Y / (X+Y+Z). Chromaticities x, y thus represent color hue and color saturation, and tristimulus XYZ adds light energy amount as the brightness of that hue and saturation x, y.

D-Cinema also defined "P3" chromaticities for Red, Green, and Blue primaries as a "minimum gamut". Conceptually this says that all projection (and presumably also all displays) will be able to represent the P3 gamut or more. Note that this is a necessary requirement for practical use of the otherwise unlimited X,Y,Z, "tristimulus" values at gamma 2.6. The P3 gamut has been broadly used in post production, and is now appearing in consumer computer displays (including laptops). Note that Rec. 709 television mastering has historically used 100 nits maximum brightness, with somewhere around 5 to 10 nits at D65 for a neutral behind-screen

surround. A dim surround for television mastering differs from the dark surround of D-Cinema.

Hidden beneath this simple overview, many issues exist that are not addressed that arise in practice. First of all, CIE 1931 is only approximate. CIE 170-1:2006 generalized color matching using "cone fundamentals" that are parametrically variable as a function of age and subtended angle of view. Even then, there remains individual variation compared to CIE 170-1:2006, which represents average color vision.

Further, color appearance varies based upon viewing conditions, including the surround behind the screen, persistence of vision from what was on screen previously, absolute brightness, and a dozen other factors.

Of immediate concern is that appearance affects apply to high dynamic range (HDR) to a greater degree than with standard dynamic range (SDR) images. This is dramatically illustrated by the example of rhodopsin cone bleaching on the retina due to prolonged viewing of bright images. It takes time for the cone pigments to replenish, and color vision is gradually changing as this happens.

Consumer computer displays (including laptops) now have sufficient brightness (e.g. 500 nits) to be considered high dynamic range.

There is also currently a challenge with the HDR standardization and use of SMPTE ST 2084/PQ and BT.2020 gamut, in that there is no accompanying "minimum max. brightness" (for ST 2084/PQ) nor "minimum gamut" (for BT.2020). There is also no "highest allowed dark level" (for ST 2084/PQ) to indicate the dark end of the brightness range.

The P3 "minimum gamut" has served a valuable role in D-Cinema, and is a de facto candidate to be a minimum gamut for wide color gamut mastering and distribution. Note, however, that it is unwise to specify a P3 gamut without an associated whitepoint. For example, D65 cannot be assumed, due to the widespread use of D60 as the P3 gamut whitepoint. A simple nomenclature such as P3_D65 or P3_D60 solves this problem. Note that a greenish whitepoint at x=.314 y=.351 is used as "DCI-P3" calibration whitepoint. Care must be taken that this whitepoint not be used for actual neutral during mastering nor presentation. It would probably be helpful if this greenish whitepoint were removed from the DCI and P3 specifications, due to ongoing associated problems and confusion.

The BT.2020 gamut utilizes primaries defined on the spectrum locus of the CIE 1931 chromaticity diagram. At any point on the spectrum locus, however, there is an implicit monochromatic (i.e. laser-like) wavelength. For BT.2020, these are specified as a dual with the corresponding chromaticities being red=630nm, green=532nm, blue=467nm. This clarifies the weaknesses of CIE 1931 CMF's. However, any CMF's will have low accuracy when blending amounts of these primaries, due to "metameric failure". This simply means that broad spectrum colors no longer are accurately created by blending such narrow primaries. This is both a weakness of CIE 1931 on average, as well as a weakness due to individual variation and subtended angle variation both being at their worst when using narrow primaries.

P3 primaries strike a balance between spectral width and achievable gamut. This has proven workable in practice, in part because P3 primary emission spectra have typically been carefully designed.

If an alternative to P3 as a minimum gamut is considered, such alternative should similarly be evaluated with respect to achievable spectral power distribution vs. metameric functionality.

If we assume that P3 is the minimum gamut, we have access to a number of professional and consumer computer displays that we can utilize. By ensuring that the P3 gamut boundary is defined by the range limits of red, green, and blue, we are able to see every color within gamut on our reference display.

However, the issue of minimum range remains. Further, range is greatly affected by the brightness of the ambient surround. Essentially, apparent contrast increases with surround brightness (known as the Stevens effect). As surround brightness goes up, mid-grey appears darker. As surround brightness goes down, mid-grey appears brighter. Mid-grey appears brightest in dark surround, such as D-Cinema.

Note that the dark range appearance of shadow areas on screen is also affected by the ambient surround. A high ambient surround masks a high onscreen black.

We therefore have two appearance factors affecting dynamic range which require attention. One is the absolute range of brightness and darkness, and the other is the ambient surround level. These must be considered both with respect to mastering reference viewing, as well as for proper reproduction of creative intent on the distributed image during presentation.

It is obvious that there is no adequate single display-referred representation for an HDR master. This implies that a suitable master must not be display-referred, but rather must reside in some neutral form. Experiments utilizing a scene-referred neutral form have worked well. However, any suitable neutral form and accompanying parametric processing could be utilized.

The parametric processing should attempt to compensate for the more prominent appearance factors. These should probably include "colorfulness" (the Hunt effect), ambient surround compensation (the Stevens effect), and compensation for the difference between mastered brightness range and presented brightness range. These should all be designed to create a consistent reproduction of the mastered appearance, despite the wide range of differences likely found in presentation devices.

One might consider masters at 250 nits, 500 nits, and 1000 nits, made in versions for bright and for dim

surround. Dark surround may not be appropriate at HDR brightnesses of 250 nits and higher due to inherent viewing discomfort at such high brightness in dark surround.

To master and distribute content that will display with intended artistic intent, the implicit choice is either multiple versions or parametric appearance compensation. The presentation display and its environment contain the information necessary to either drive the parametric appearance processing, or select among multiple versions (assuming multiple versions are available).

There has been substantial recent effort in pursuit of the reproduction of intended appearance. Most of the required processing steps have working examples at this point. With these processing steps, much of the required mastering methodology and accompanying parametric appearance compensation processing can be demonstrated.

Next steps include further refinement and testing, as well as additional discussion and exploration of feasible deployment strategies. It is hoped that the fundamental nature of the issues discussed here will help to create interest in finding a path forward in pursuit of the consistent presentation of creative intent in our rapidly changing industry.

Professional Display Committee

Chair: Jim Fancher
Vice-chair: Gary Mandle

Working closely with the Advanced Imaging Committee, the Professional Display Committee has been investigating best practices for surround lighting during mastering and critical viewing. In our work with characterizing professional displays it became apparent that old standards for surround lighting were not appropriate for High Dynamic Range (HDR) displays. We have been in touch with SMPTE and will be investigating the recommendations in ST 2080-3. In addition to bringing the Committee up to date on emerging display technologies, we have also participated in several demonstrations of HDR displays.

Motion Imaging Workflow Committee

Chair: Greg Ciaccio
Vice-Chair: Tim Kang
Vice-Chair: George Joblove

Current Committee focus: ACES Education and ASC Website Section

For the last few years, the ASC Motion Imaging Technology Council's Motion Imaging Workflow Committee has continued to focus on helping to educate and guide industry professionals on ACES benefits parallel with efforts by the AMPAS Science and Technology Council. In addition, the new ASC website will feature a section devoted to ACES.

The Committee is composed of key individuals in a variety of positions involved in production and post, who provide valuable real-world feedback. Frequently, prominent cinematographers attend and contribute with fresh perspective.

Since the introduction of ACES v.1.0, a significant number of productions have used ACES. A fairly comprehensive list can be found here:

http://www.imdb.com/search/title?colors=aces

Our Committee continues to work in conjunction with the AMPAS Sci-Tech Council and has created a clear definition of ACES:

The Academy Color Encoding System (ACES) is becoming the industry standard for managing color throughout the life cycle of a motion picture or television production. From image capture through editing, VFX, mastering, public presentation, archiving and future remastering, ACES ensures a consistent color experience that preserves the filmmaker's creative vision. In addition to the creative benefits, ACES addresses and solves a number of significant production, post-production and archiving problems that have arisen with the increasing variety of digital cameras and formats in use, as well as the surge in the number of productions that rely on worldwide collaboration using shared digital image files.

The upcoming new ASC website (at the time of this writing) will include an ACES section comprised of general and Cinematographer-centric ACES information,

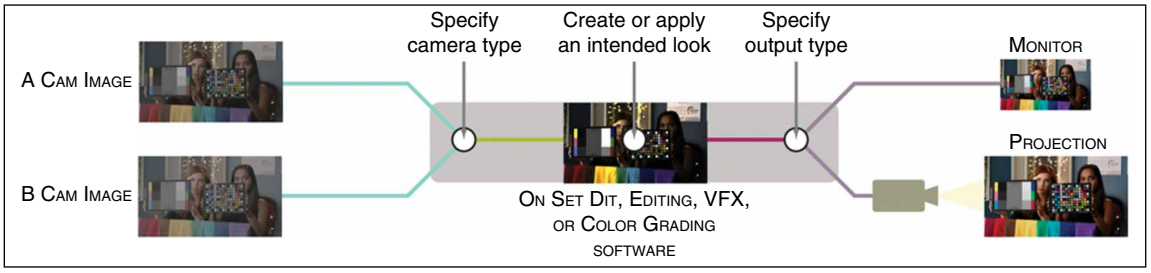


FIGURE 9. Basic ACES Workflow.

testimonials, case studies and current highlights. A forum has been established to allow for ACES discussion and collaboration, and has been instrumental in functioning as a central repository for our industry. This forum, ACES Central, can be found here: www.acescentral.com. The ASC's ACES site will include a link to ACES Central.

With so many new imaging advances being introduced concurrently (increases in spatial resolution, dynamic range, color gamut, etc.), it is vital to faithfully process and preserve creative intent by making sure that no bits are lost along the way. This is especially important now as interest in high-dynamic range (HDR) imagery has taken center stage, requiring a standard which can not only accommodate the extra range needed, but can more easily produce the numerous versions needed for new and legacy displays of varying brightness capabilities.

As ACES user experiences are shared within our industry, the practical benefits are being realized. At least one major studio has expressed great interest in integrating ACES into their production and post pipelines as the benefits of ACES have been realized in cost & time savings, as well as in archival.

More information regarding ACES is available at http://www.oscars.org/aces

Digital Intermediate Committee

Co-chair: Joshua Pines
Co-chair: David Reisner

As all are well aware, the ASC CDL (American Society of Cinematographers Color Decision List) is very well established and nearly universally used. Part of this is due to its utility, part the cleanliness and simplicity of its design, and part is due to the ASC CDL's stability. As such, we are reluctant to make changes without significant motivation and consideration.

But after extensive discussion and consideration, at this point, the Committee has decided there are a few areas where enhancements that are consistent with the original design and whose implementation is not disruptive may be warranted. There are also a few more disruptive changes or additions being considered.

There have been clear needs for additional metadata, particularly some extension of the mechanism for connecting shots and corrections. Although provided for in v1.01 and largely ignored, there is (finally) an interest in metadata documenting shooting and viewing transforms used before and after the ASC CDL. We will rehabilitate this area with substantially expanded guidance on usage, and provide a few extensions.

Given the expansions into wider color gamuts and the much larger number ranges of representations like OpenEXR in ACES, there is probably a good argument for a new saturation function. We will keep the existing Sat() function and add a new Sat2() function to address these uses. We are still evaluating the appropriate definition for Sat2().

There continue to be some calls for six-axis color correction. While during original introduction of the ASC CDL color correction system manufacturers were NOT willing to implement a new six-axis correction, it may now be possible that, if we provide the specific desired math, they may be willing to include the implementation. People who call for six-axis usually do not have the combination of color science, math, and hands-on experience to understand the strength and capability of implementation required. We tried implementing fixed six-axis correctors and they didn't actually meet colorists' desires, but providing additional options and refinement makes six-axis complicated for an onset tool. Since that experiment, the DI Committee has created and tested several approaches for a full, parametric six-axis corrector. We will revisit these issues in a wide color gamut, High Dynamic Range, floating-point / ACES world.

Aside from implementation issues, we must caution our user base that parametric six-axis correction is a power so great that it can only be used for Good… or Evil. It is very simple to take an image to completely unrecoverable places, at which point you will be intensely glad that the ASC CDL is a non-destructive system.

Once the metadata and Sat2() issues are addressed, we will at long last take the ASC CDL to SMPTE RDD (Registered Disclosure Document). An RDD will serve most of the functions of a Standard, but not require an open negotiation about the ASC CDL's definition – keeping control within the ASC Motion Imaging Technology Council DI Committee.

To get the current ASC CDL specification, send an e-mail to asc-cdl@theasc.com; an auto-responder will send terms and instructions. For additional information about the ASC CDL or Digital Intermediate Committee, contact Joshua Pines at jzp@technicolor.com or David Reisner at dreisner@d-cinema.us.

Plenoptic Committee

Co-chair: David Reisner
Co-chair: Joshua Pines

The word "plenoptic" means "Of or relating to all the light, travelling in every direction in a given space." The most general form, a Light Field camera, attempts to record the intensity, direction, and possibly phase of

all the light that hits its imager. From that data, many versions of the image can be computed – various focal lengths, depths of field, effective angles of view, sorting or layering of objects by position. Obviously recording and manipulating that collection of data requires very different storage formats and manipulation techniques than do traditional 2D camera data.

Although full Light Field is rather a specialty approach, being pursued by only a small number of companies, and with integration into production procedures and workflows only just starting to be explored, point cloud imaging, depth imaging, and things like Virtual Reality cameras and other techniques for capturing very wide or 360-degree surround imaging have related needs for storage formats and manipulation techniques.

These types of imaging are dependent on the easy availability of high quality, and hopefully moderately priced, digital imagers. And critically dependent on both high bandwidth and high capacity storage systems, and on anywhere from large to exceptional amounts of computing power. Both storage and compute are increasingly available in the Cloud from sources like Google and Amazon, and in stand-alone hardware from companies like Nvidia and others.

The Plenoptic Committee will participate in addressing all of these issues in the context of entertainment imaging. We will especially work to make sure that the needs of feature motion pictures are addressed in other industry work, and also contribute to education about and awareness of high quality imaging for mobile devices and other delivery devices.

The Plenoptic Committee was formed in response to a liaison request from the ISO/IEC JTC 1/SC 29/WG1 JPEG Pleno Working Group.

"JPEG Pleno is a project encompassing future image representations that will move beyond the traditional planar image representations. These non-planar representations can include omnidirectional, depth enhanced, light fields and point cloud imagery. JPEG is taking a holistic approach to cover the entire content workflow from capture, production, post-production and rendering. … JPEG is interested in use cases and requirements for the cinematic and broadcast production environments in order to meet the needs of potential customers in those fields."

This is very new and not widely available technology. We have some cinematographer members who have experience with these types of imaging, but so far only a few. It is a good sign that the technology-oriented standards groups are seeking input from the community of artists who would ultimately be responsible for creative and artistic use of these technologies and techniques.

As resources are made available, we will be happy to participate in exploration of these techniques. In addition to technical and artistic, one critically important part of that exploration will be how the business and production process can accommodate the quite different distribution of need for cinematographer time in a project. Cinematographers are the key authors of image look and creative intent. In the plenoptic types of production, many of those decisions will be made at much later points in the project, and with a dangerously large flexibility. Cinematographer involvement will be needed through production and post to ensure that a creative vision and "art" is realized.

In this rapidly changing world, we believe this powerful technology will almost certainly have impact on our industries. The ASC Motion Imaging Technology Council and the ASC Membership will keep actively abreast of and involved in developments and (when funding and equipment are available) testing, to help guide these new techniques toward results that will support the filmmaker's creative vision and provide satisfying audience experiences.

Joint Technology Committee on Virtual Production

Chair: David Morin
Co-Chair: John Scheele

Over the period since the last SMPTE report, the Joint Committee on Virtual Production of the ASC continued its series of case studies on the broadening use of realtime computer graphics on set.

Case Study: "The Jungle Book"

The eleventh meeting of the VPC was held on Wednesday December 14th at the flagship Dolby Cinema Vine Theatre, located at 6321 Hollywood Blvd, Los Angeles, CA 90028.

Our meeting #11 featured the definitive case study on the virtual production of the motion picture "The Jungle Book". The case study was led by Rob Legato, ASC, who architected the virtual production workflow and was visual effects supervisor, second unit director and second unit DOP on the movie. Joining Rob were Director Jon Favreau, Producer Brigham Taylor, and Animation Director Andy Jones.

For the occasion, we saw excerpts from the movie in Dolby Cinema with Dolby Vision High Dynamic Range laser projection in 3D, augmented with 38 Dolby ATMOS speakers, in a special color grade done specifically for Dolby Cinema release.

Additionally, the "Gnomes & Goblins" *Virtual Reality Experience*, also directed by Jon Favreau,

FIGURE 10. Directed by Jon Favreau, "The Jungle Book" tells the story of a man-cub named Mowgli who embarks on a journey of self-discovery with the help of panther Bagheera and free spirited bear Baloo, after a threat from the tiger Shere Khan forces him to flee the jungle. http://movies.disney.com/the-jungle-book-2016 - With only one child actor as live action element, extensive previsualization and on-set visualization were needed to realize this "live action" remake of the classic animated movie.

was available for attendees to experience prior to the meeting. You can find more information about "Gnomes and Goblins" here - https://drive.google.com/open?id=0B6BP7N9l3-Z4aEZGb0F2Q0JmNEk.

The discussion that followed "The Jungle Book" presentation was of great interest, and a prime example of the value that can be derived from our committee meetings, as members of "The Lion King" production who were in the audience (namely producer Jeff Silver and cinematographer Caleb Deschanels, ASC) engaged in a conversation with "The Jungle Book" team about their upcoming production.

Subsequently, "The Jungle Book" team joined "The Lion King" team and are now together building a state of the art collaborative virtual production system for that movie.

The Virtual Production Track at FMX 2017

For the sixth year in a row, Virtual Production committee chair David Morin curated the "Virtual Production Track" at FMX2017 in Stuttgart, Germany. The track showcased nine case studies that took place on May 4th and May 5th 2017. The presentations covered the use of previsualization and virtual production in the following films: "Logan", "Warcraft", "Allied", "Deadpool", "Ghost in The Shell", "Doctor Strange", "Beauty and the Beast", and "Rogue One". More details on the program can be accessed here - http://www.fmx.de/program2017/list?t=687.

Brigham Taylor
Producer

Jon Favreau
Director

Rob Legato
VFX Supervisor

Andy Jones
Animation Supervisor

FIGURE 11. Above: presenters at meeting #11 of VPC that took place on December 14th 2016.

FIGURE 12. A series of six case studies on virtual reality for production were presented in Stuttgart, Germany on May 4th and 5th 2017

Future Activities

The Virtual Production Committee will continue to pursue its goal of educating and helping define the new workflow, and is currently planning its meeting #12 for late 2017. Meeting 12 will be the last in the cycle of 12 case studies that we set out to do when we created the VPC in 2010. Accordingly, we plan to reassemble most of the presenters from previous meetings in a substantial day-long conference that will celebrate the transition of virtual production from "the age of the pioneers" to a more affordable toolset available to all filmmakers, thanks to development in the new emerging field of virtual reality.

Participation is encouraged. Those interested may contact: David Morin, Chair, davidmorin@davidmorin.com. John Scheele, Co-Chair, johnscheele@gmail.com.

Joint Technology Committee on Virtual Reality

Chair: David Morin
Vice-Chair: Michael Goi, ASC
Vice-Chair: Mike Sanders, Activision

The first meeting of the VR Committee was held Wednesday January 11th 2017 at Jaunt Studios in Santa Monica, CA, and featured a case study of cinematic VR projects developed by the team at Jaunt, including the development and production of the Jaunt ONE VR camera engineered by Koji Gardiner, and the VR film "Under The Canopy" directed by Patrick Meehan. The first meeting was attended by about 60 people.

The presentations were followed by a lively discussion about what remains to be done to develop the new cinematic VR medium, and how cinematographers can learn about it. Multiple workgroup ideas were presented, and at this time a workgroup on VR terminology is under way, led by Evan Goldberg from Walt Disney Animation Studios, along with a workgroup on cinematic VR production, led by past president of the ASC Michael Goi, ASC.

Subsequently, Michael Goi agreed to become vice-chair of the VR Committee, along with Mike Sanders from Activision.

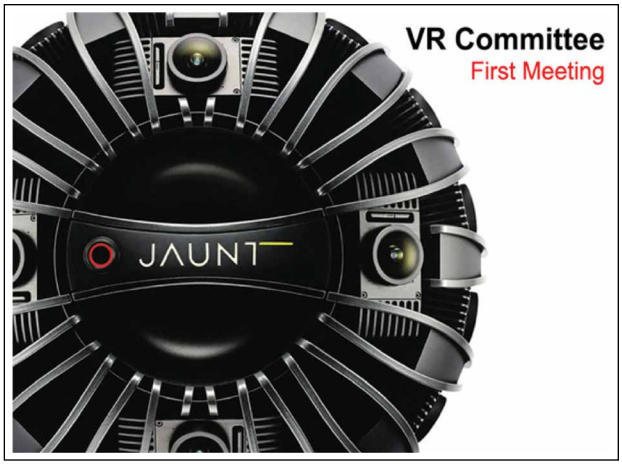


FIGURE 13. The Joint Technology Committee on Virtual Reality (the VR Committee) ASC Motion Imaging Technology Council in 2016 with the mandate to explore the role of the cinematographer in the creation of virtual reality experiences. The International Cinematographers Guild joined the committee shortly after its inception.

Digital Archive Committee

Chair: Garrett J. Smith

The ASC Motion Imaging Technology Council Digital Archive Committee continues to examine the pros and cons of today's evolving storage methodologies - nearly a decade after the Academy's Digital Dilemma report.

Nearly every use case from the most independent film to the biggest of studio tent poles indicates that there is no consensus on the best way to archive digital data.

We are committed to examining everything from hard drives, optical media, cloud and even digital 35mm black and white storage solutions. (Yes, more than one studio still creates 35mm YCM's and there have been presentations to the committee on two different 'digital data on film' solutions.)

We also plan to schedule presentations on all flavors of cloud and hybrid cloud archiving in the upcoming year.

In the last 100 years of our industry, we have faced such unexpected issues as 'vinegar' and 'gunpowder' threatening the life of our images. In today's data storage world we now have to learn about the effects on our elements of things like: *"coercivity and residual magnetism for current GMR (Giant MagnetoResistance) and SMR (Shingled MagnetoResistance) recording techniques"* – to name a few.

It is obvious that our industry is in a state of fluctuation for the foreseeable future. The ASC Motion Imaging Technology Council strives to help deal with the dynamics of an ever evolving landscape in order to preserve our images as intended by the artists for decades and longer.

SSIMWave HDR Evaluation Working Group

Coordinator: W. Thomas Wall

Despite a lapse in activity since the last report, this effort is again alive and very active:

At a Working Group meeting a year ago, a range of plans and issues were discussed to accomplish the study of:

- how well the original creative intent of cinematographers and colorists is preserved in the delivery of High Dynamic Range, Wide Color Gamut material to consumer devices
- whether the SSIMWave SSIMPlus perceptual quality metric software reflects what DPs and colorists see, when applied to HDR, WCG material.

The resulting overall plan was simple (in principle):

- Set up an initial version of the actual testbed and test environment that will be required for this evaluation, at Dr. Zhou Wang's visual studies laboratory at the University of Waterloo, Canada – with all hardware, software, and test methodologies in place and working, even if in initial form.
- Once we know the exact requirements for this testbed (hardware, software, physical layout, personnel, etc.), proceed with a trial setup here in Los Angeles.
- Demonstrate the proposed test procedures and methodologies to this Working Group, then to industry partners, and to various content distributors, with the actual hardware and (initial) software that will be used – to receive feedback and suggestions, but also to make concrete not just the concepts and motivation behind these tests, but their actual capabilities and potential benefits.

In that way, we hope to gain additional buy-in and participation among all of the parties that are interested in these studies, when we do the actual evaluations.

Unfortunately, not long after that meeting, there appeared a series of roadblocks that halted progress – financial issues, limitations of then available technology, institutional reluctance, and availability of the needed people, among others.

Many of these hurdles have recently either been removed or mitigated.

On the technology front,

- There are now high-end plug-in adapter cards (with the appropriate daughter cards) and external adapters available that can drive 4K HDR reference monitors with 12-bit SMPTE 2084/PQ-encoded HDR data at the high data rates required, over quad 3G-SDI at up to 30 frames/sec. Supported software to drive them is now available. (Going beyond that still requires dropping down to lower bit depths and sub-sampled color. And the vagaries of the HDMI protocol renders that interface unusable for our purposes. Discussions with vendors are on-going to remove these interface limitations.)
- There are now NVMe SSD drives with adequate capacity that can reliably provide data at those very high sustained rates (without requiring very expensive external RAID arrays).
- GPUs are now available with the capability of driving 12-bit color pipelines that were not previously available, with interface connections that can support that data throughput.
- Motherboards and workstations are available that support PCIe gen 3 with adequate lanes and sufficient physical space for our needs.

Although still requiring a high-end PC for our tests, it is now feasible to construct such systems without requiring a bank-breaking investment. Which in turn means it is now feasible to ask for support and help from industry partners to provide such systems during our testing. Discussions have begun with HP, NVIDIA, and Blackmagic Design, among others, to provide those systems for our study testbeds in Los Angeles.

- And finally, new HDR reference monitors have appeared and become more available outside of large post-production facilities.

Current status

First, we now have expanded participation from the University of Waterloo:

Dr. Wang's laboratory at the University of Waterloo has recently received a grant to fund their efforts. This has allowed several positive developments, including:

- In addition to SSIMWave's Dr. Abdul Rehman and Dr. Kai Zeng and their staff, graduate students in Dr. Wang's visual studies program will now be devoting time to this study. We have been making progress educating them in the differences between the needs and characteristics of digital cinema vs. those of standard Rec. 709 "video".
- Their University of Waterloo Visual Studies lab has now acquired a Canon DP-V2420 1200 nit, 4K HDR reference monitor, for accurately displaying PQ-encoded HDR WCG material.
- After a series of tests, they have recently obtained a Blackmagic UltraStudio 4K Extreme capable of driving that reference monitor at the maximum data rate it can currently display. (During a process of inevitable trial and error with hardware and software from various vendors, the staff has been working with Canon – and with the considerable help and support of Mark Thompson and Sean Manton at Blackmagic Design, and input from experts such as Gary Demos, as well as others – to get this reference monitor working at its full potential, as needed for this study – which, it turns out, is at the bleeding edge of current technology to achieve. But with the hard work of all of the above, progress is being made.)
- A computer system capable of driving these displays in our tests is being put together and tested.
- Work has begun on the custom software required for the simultaneous, synchronized display of such imagery on two reference monitors as required for this study.
- In addition to this ASC Motion Imaging Technology Council Working Group's study, Dr. Wang and his team have also initiated a study of HDR as viewed on consumer UHD HDR television sets. He and his students and researchers understand the huge challenges involved in that, but feel the urgency of establishing scientific standards regarding the viewing of HDR, WCG material. Although more directly related to the work of the ASC Motion Imaging Technology Council's UHDTV Display Committee – which is actively involved in such evaluation of how cinema-quality HDR imagery is displayed on the various brands and technologies of consumer HDR displays – than this Working Group's study – which is not concerned with evaluations of consumer TVs or set top boxes – lessons learned in the setup of their new study, as well common hardware and software required, will help in developing our evaluation of the delivery of HDR as evaluated by experienced DPs and colorists.

In regards to test material, in addition to the ASC's ICAS files:

- We have obtained permission from Netflix to use the original ACES-SMPTE 2065 graded master of Curtis Clark, ASC's film-noir short "Meridian", shot and graded for HDR, along with three SMPTE 2084/PQ-encoded and compressed HDR versions that Netflix previously released publicly for test purposes.

We therefore now have the first complete set of files needed for this study: an original, "as approved" graded master in linear ACES openEXR format, and three "as delivered" examples of that same master file after being transcoded, encoded and compressed to varying levels for distribution to Netflix customers at different bit rates.

[[I've seen that ACES graded master of Meridian in a grading theatre on a Sony BVM-X300 HDR reference monitor – it's stunning!]]

- Andy Maltz and Alex Forsyth have agreed to allow us to use the Motion Picture Academy's ACES Next Generation Cinema Technology reference files in our tests.
- Don Eklund and the UHDTV Display Committee of the ASC Motion Imaging Technology Council have shot reference test material specifically aimed at evaluating HDR display. They are in the process of final color grading. We are working with him and his Committee in that effort.
- We are also investigating the use of HDR test material from Joe Kane – some of which is specifically designed to both highlight and stress the display of HDR, WCG images at resolutions up to 8K. With the help of Jerome Dewhurst and others at Roundabout Entertainment, we are obtaining graded ACES 2065-1 AP0 versions for our study.
- The Next Generation Cinema Display sub-committee of the ASC Motion Imaging Technology Council has begun actively seeking test material for evaluating the latest HDR, WCG cinema display technologies. Co-chair Michael Karagosian is actively working with us to assemble a joint repository of such test material with all of the characteristics required to fully explore those capabilities, and to make it available to the industry at large.

More industry partners have expressed interest in cooperating in this study. For example:

- Thanks to Jerome Dewhurst at Roundabout Entertainment, Roundabout has agreed to work with our

Committee, and host testbeds for our evaluation once that is finalized. They join FotoKem, EFilm/Deluxe, and Sony that have previously expressed their interest in working with us.

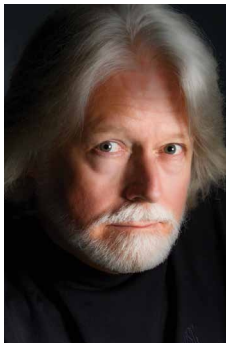
- We are in discussions with Michael Cioni at Light Iron/Panavision for possible use of HDR test material used by Panavision with their new DXL camera.

So, bottom line:

There is still lots to do. But we are again making progress toward performing this study of the delivery of HDR, WCG narrative imagery, as evaluated by experienced professionals, and how it can be objectively as well as subjectively evaluated.

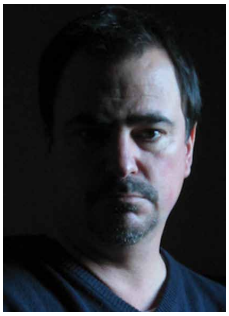
Inquiries regarding the ASC Motion Imaging Technology Council should be sent to Delphine Figueras: delphine@theasc.com

About the Authors



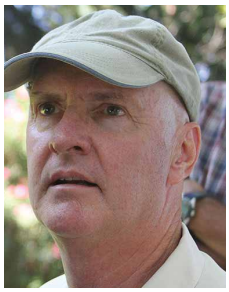
Curtis Clark, ASC, studied theater at the Art Institute of Chicago's Goodman School of Drama and Cinematography at the London Film School. He began his career by shooting and directing documentary films in Britain before transitioning to shooting feature films and TV commercials in Britain and the US. Following the success of his short film, *The Arrival*, Clark then completed his highly praised short film *Eldorado*. He recently completed his latest short film, *Meridian* (Netflix), a creatively accomplished work that has already gained the status of an essential demonstration for HDR imaging. Clark is the Chairman of the ASC Motion Imaging Technology Council and a current member of the ASC Board of Governors. Since its inception in 2003, the Committee under Clark's leadership has achieved a series of notable successes including its collaborative work with DCI, LLC (DCI) to produce standardized evaluation material for assessing the performance of digital projectors and other elements of DCI standards-based digital cinema systems, as well as the 2009 Camera Assessment Series and 2012 Image Control Assessment Series. The ASC Motion Imaging Technology Council, at Clark's instigation, embarked on the development of a groundbreaking project to create cross-platform data exchange for primary RGB digital color correction known as the ASC CDL. The ASC CDL was recognized by the Academy of Television Arts and Sciences with a prestigious 2012 Primetime Emmy Engineering Award. Clark also received an AMPAS Technical Achievement Award recognizing his work developing the ASC CDL. Clark was a recipient of the prestigious ASC Presidents Award.

David Reisner received the 2014 Academy Technical Achievement Award and the 2014 Hollywood Post Alliance Judges Award for Creativity and Innovation. He was recognized in the 2012 Primetime Emmy Engineering Award as a Co-Designer of the ASC CDL, now used almost universally in the workflow of motion pictures, scripted TV, and visual effects turn over. He was a Lead Designer of the ASC-DCI StEM Standard Evaluation Material that was used to determine the quality required for the deployment of digital cinema. He was the Vice-Chair of the SMPTE Working Groups responsible for the digital cinema imaging and security standards. Over 97% of cinema screens worldwide now use digital cinema. Reisner also had leading roles in activities including design and production of the ASC-Producers Guild of America (PGA) CAS Camera Assessment Series and elements of the ACES. He made one of the first proposals for the Virtual Print Fee model used to fund the digital cinema rollout. Reisner's "firsts" include programmable portable computers, the handheld video jukebox, and VLIW computer architecture—one of the enablers of modern multiprocessor computing. He made early contribution to the introduction of neural networks—the basis of modern AI and Machine Learning. He has shot celebrity and fashion for books and magazines including *Vogue Italia*, produced concerts internationally, and tr[a]ined killer whales. Reisner is well published in books, technical articles, and has spoken widely, including manned space exploration at the 2014 International Space Development Conference. He is a member of SMPTE; the founding Secretary of the ASC Motion Imaging Technology Council and an ASC Associate; a Member of the Visual Effects Society; and Chairs committees for the Academy Scientific and Technical Awards.



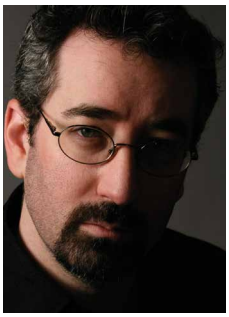
David Stump, ASC, is a working DP, visual effects DP, visual effects supervisor, and stereographer, earning an Emmy Award, an Academy Award for Scientific and Technical Achievement, and an International Cinematographers Guild Award. He is currently the Chairman of the Camera Committee of the ASC Motion Imaging Technology Council and a member of the AMPAS Science and Technology Council, where he chairs the Next Generation Cinema Technology Work Group and participates in the AMPAS

ACES project. Under his guidance, the combined efforts of the PGA and the ASC produced both the ASC-PGA Camera Assessment Series and the ASC-PGA ICAS, which are side-by-side comparisons of virtually all of the high-end digital cinema cameras against film. He has lectured and taught classes in cinematography and visual effects and has spoken at many conferences and trade shows, including the National Association of Broadcasters and the International Broadcast Convention.



Bill Bennett, ASC, has been a cinematographer for over 35 years, primarily shooting television commercials for hundreds of major clients: Ford, Lexus, Coca Cola, Apple Computer, American Airlines, McDonalds, and Budweiser. Bennett had the great honor of being the first cinematographer, with a career consisting of primarily shooting television commercials, to be invited to join the American Society of Cinematographers. In 2016, the ASC presented Bennett with the President's Award at the 30th annual ASC Awards Show. He is currently serving as the Vice President at ASC. Bennett often advises ARRI, Zeiss, and others on equipment design.

Michael McDonough, ASC, BSC, is a writer, director, producer, and cinematographer. He studied fine art at The Glasgow School of Art for undergraduate and The Royal College of Art, London for his Masters. A year spent in Rome on the Prix De Rome scholarship led to a confirmation of a love of Cinema as an art form. McDonough has 20 years of experience as a cinematographer with such directors as David Mackenzie (*Starred Up*), Rodrigo Garcia (*Albert Nobbs*), Terence Davies (*Sunset Song*), Stephen Frears (*Lay the Favourite*), Michael Radford (*Elsa and Fred*), and Lawrence Kasdan (*Darling Companion*) in film, and many more in television. He has received an Independent Spirit Award Nomination and a London Evening Times award nomination. In addition to his membership in the ASC and the British Society of Cinematographers, McDonough is also a member of the Directors Guild of America. In 2015, he directed an episode of the popular television series he was shooting for AMC, *Fear the Walking Dead*. This came on the shoulders of a 16 part promotional series for the same series that garnered an Emmy Nomination in 2016 for Best New Media and Short Form Program.



Jay Holben is an independent director, producer, and formerly a cinematographer for more than a decade. A lead contributor to *American Cinematographer* magazine, former technical editor *for Digital Video magazine* and lighting columnist for *TV Technology* magazine, Holben is the author of two books on cinematography: *A Shot in the Dark* and *Behind the Lens*. He is an international lecturer on the subject and the Co-Chair of the ASC Motion Imaging Technology Council Lens Committee.

Don Eklund serves as the Chief Technology Officer for Sony Pictures Entertainment. He has helped launch multiple consumer entertainment formats since starting his career at Sony. He codeveloped and staffed the operation that launched DVD at Sony Pictures and went on to oversee the development of software tools and hardware systems which supported compression, authoring, and quality control for Blu-ray. Eklund participates in a number industry standards organizations and consortiums, which focus on next generation entertainment.

Bill Mandel is Vice President Industry Relations at Samsung Research America, representing Samsung in various industry groups on topics of HDR, workflow technologies and picture quality. Previously, in over 20 years at Universal Pictures, Bill worked with technology companies and content licensees on digital format launches, digital distribution and media technologies growth and development of digital media ecosystems. He is known for advancing new forms of digital media, including DVD, Internet VOD/EST, DVHS, STB/TV streaming, Blu-Ray/HD DVD/BD-Live, 3D, High Dynamic Range (HDR), UHD and interactive extensions to digital distribution.

Michael Karagosian is the President of MKPE Consulting LLC, a consultancy based in Los Angeles, CA. He is an accomplished leader in entertainment technology, with expertise in negotiation strategy and in all aspects of patent development and defense. Major accomplishments include the negotiation

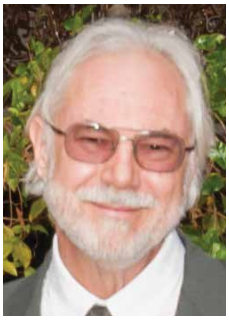
of virtual print fee subsidies with the major Hollywood studios for up to U.S. $300 million of cinema equipment in Ireland, Philippines, and South America. He was a Co-Founder of CinemaAcoustics, a division of Peavey Electronics, and a member of the Board of Directors for pioneering 3D conversion company In-Three. Karagosian represented the technology interests of the National Association of Theatre Owners for 11 years during the digital cinema transition. He has an engineering degree from U.C. Berkeley, with graduate work at Santa Clara University and UCLA. Karagosian is a Co-Chair of the ASC Motion Imaging Technology Council on Next Generation Cinema Display, a SMPTE Life Fellow, and a Life Member of the Audio Engineering Society.

Eric Rodli has been involved in the management and development of entertainment technology since the late 1980s when he became the President of Iwerks Entertainment; a pioneer in large format film, motion simulation theaters, and other immersive technologies. He subsequently had senior roles in a variety of entertainment and media organizations, including being a partner in the entertainment consulting practice of PwC as well as the President of Kodak's Motion Picture Division. He currently provides strategic advisory services to companies in the entertainment technology industry. He is an Associate member of the ASC. Rodli received a BA in economics from the University of California, San Diego, and MBA from the University of Chicago.

Steve Schklair, is a producer, cinematographer, and the founder and CEO of 3ALITY. Schklair led the development of the best known digital 3D camera systems, and served as the Technical Producer on the groundbreaking U23D movie released in 2007. He has provided technology and expertise for 3D films including The Hobbit, X-Men, The Martian, and Transformers. Schklair also served as 3D producer for the Russian epic, Stalingrad, directed by Fedor Bondarchuk. He has been noted for leading the 3D television movement, shooting the first live 3D broadcasts from the NFL, the BCS Championship, sports programming for BSkyB, the Super Bowl, and the World Cup, along with live concert films such as Katy Perry, One Direction, and The Black Eyed Peas.

Prior to 3ality, Schklair was a Vice President of Digital Domain during the production of such films as Apollo 13, The Fifth Element, Titanic, and Terminator 2:3D. He was also creative director for R/Greenberg Associates, and Executive Producer of The Columbus Project for computer graphics and interactive media pioneer Robert Abel.

In 2014, the International 3D and Advanced Imaging Society recognized Schklair and 3ALITY with the prestigious Century Award. Schklair is an associate member of the American Society of Cinematographers (ASC), a member of the Producer's Guild of America (PGA), and an award-winning member of the VES.



Gary Demos has been a pioneer in the development of computer generated images for use in motion pictures, digital image processing, and image compression. He was a founder of Digital Productions (1982–1986), and was awarded an Academy of Motion Picture Arts and Sciences Scientific and Engineering Award in 1984 along with John Whitney Jr. "For the Practical Simulation of Motion Picture Photography By Means of Computer-Generated Images." Gary also founded Whitney-Demos Productions (1986–1988), DemoGraFX (1988–2003), and Image Essence LLC (2005 to present). Gary Demos is the recipient of the AMPAS 2005 Gordon E. Sawyer Oscar for lifetime technical achievement. Gary is actively involved in the ASC Technology Committee and has worked on the AMPAS ACES project. Gary has presented numerous papers at SMPTE, given a SMPTE webinar, is a SMPTE Fellow, and received the 2012 SMPTE Digital Processing Medal. Gary is the inventor of approximately one hundred patents.

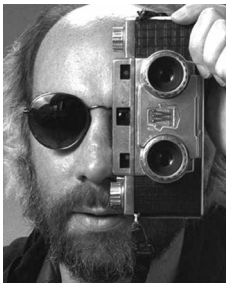
Jim Fancher developed next-generation technology in digital asset management for Deluxe Digital Media in Burbank, CA. Previously, he was a Chief Science Officer at the Thomson Corporate Research facility in Burbank, where he worked on cluster computing architectures for image processing, 3D color correction systems, and digital asset management technology. As a Chief Technology Officer for Technicolor Creative Services and the post-production arm of Technicolor, he was involved in the development of color management systems, image processing and media asset management. Fancher has been a part of managing Technicolor's world class DI facility (formerly known as Technique) as well as the deployment of DI processes to Montreal and New York. Prior to his engagement at Technicolor, he was a Chief Science Officer for Pacific Ocean Post, where he started POP Sound, POP Film, which won two Academy Awards for visual effects, and the

POP-Cinram DVD center. Fancher holds a bachelor degree in Chemistry from Princeton University, numerous patents, and has been a member of SMPTE since 1974.

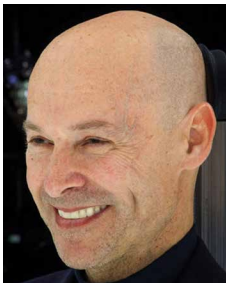
Gary Mandle has worked within Sony Electronics in the development of new display and imaging technologies as a design engineer and product manager. Products that Mandle has been involved with include the introduction of Sony's BVM and PVM CRT model lineup, the introduction of LCD for professional monitoring, the implementation of Sony's digital cinema projection systems, both GLV and SXRD technologies, and the development of Sony's current OLED technology. Mandle has authored several SMPTE, IEEE, and SID journals and has been a contributing author of several technology text books with regard to CRT, Plasma, LCD, and OLED. Other areas of work include the design of camera image stabilization systems and CCD sensor development where he holds multiple patents. Memberships include CIE, IEEE, SID, OSA and he is an associate member of the American Society of Cinematographers as well as a board member of SMPTE as Western Area Governor which includes San Francisco, Sacramento, the Northwest, and Rocky Mountain sections.

Greg Ciaccio is a Managing Partner of [RE] Design Group, primarily focused on finding new technology and workflow solutions for the Motion Picture, Television, and VR/AR/MR industries. Previously, Ciaccio served in technical management roles for the respective Creative Services divisions for both Deluxe and Technicolor. Key developments include the first DP Lights deployments for Technicolor and full near set dailies solutions for Deluxe Television. Ciaccio is a member of SMPTE, ASC Motion Imaging Technology Council, AMPAS Sci-Tech Council, HPA, and DCS. He holds a BA degree in radio-television-film from California State University, Northridge, where he currently teaches post-production part time.

Tim Kang is a Los Angeles-based cinematographer, working in the film and television industry primarily as a Director of Photography on narrative, commercial, music video, and documentary projects. In addition to multiple features, pilots, and shorts, his list of commercial clients includes: Cover Girl, Delta, LA Kings, Disney Interactive, DreamworksTV, NBC Universal, and YouTube. He has taught cinematography classes and seminars at AFI, Chapman University, and Woodbury University. For formal training, he received a Master of Fine Arts in cinematography at the renowned American Film Institute Conservatory and proudly received mentorship from Stephen Lighthill, ASC; Robert Primes, ASC; David Stump, ASC; Greg McMurry, ASC; and Ron Garcia, ASC. He previously studied biomedical engineering at Johns Hopkins University, worked in the scientific imaging world for seven years at Mount Sinai School of Medicine, and developed his photographic skills in the streets, subways, and byways of New York City.

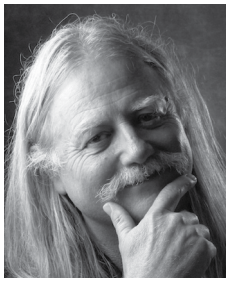


Joshua Pines is the Vice President of Imaging Research and Development, Technicolor Digital Intermediates which provides the motion picture industry with digital color correction processes for theatrically released films. Pines is in charge of imaging and color science projects. He joined Technicolor after more than 10 years at Industrial Light & Magic, where he supervised their film scanning/recording department from its inception, and worked extensively with both traditional and digital cinema technologies. He started his career teaching film courses at the Cooper Union in New York City after earning a degree in electrical engineering there. He began working in visual effects at MAGI in 1982 at the tail end of their work on *Tron,* went on to lead the computer graphics division at R/Greenberg Associates in New York City, and then supervised film effects and film recording at Degraf/Wahrman in Los Angeles before working for ILM. He has received a Technical Achievement Award from the Academy of Motion Picture Arts and Sciences, and has credits on numerous feature films.



David Morin is the Chairman of the Joint Technology Committee on Virtual Production, a joint effort of six Hollywood-based organizations: the American Society of Cinematographers (ASC), the Art Director's Guild (ADG), the Visual Effects Society (VES), the Previsualization Society, PGA, and the International Cinematographers Guild (ICG). He was a past Co-Chair of the "ASC-ADG-VES Joint Technology Committee on Previsualization," a committee that helped define the role of previsualization in the film industry, and he just started a new ASC-ICG joint Committee on VR, to study VR from the cinematographers point of view. He also organized the first "Academy Summit on Open Source Software" on behalf of the

Science and Technology Council of the Academy of Motion Picture Arts and Sciences. Morin earned a BScA degree in computer science from Laval University, Quebec City, Canada, and has participated in the development of motion capture and 3D software since *Jurassic Park* at companies such as Softimage, Microsoft, Avid Technology, and Autodesk. Today he is president of David Morin, LLC, a diversified consultancy specializing in immersive production, working with such clients as the Academy of Motion Picture Arts and Sciences, Arri Inc., Autodesk, and others. He works from his base in Los Angeles, CA.



Garrett J. Smith is currently senior creative liaison at Entertainment Technology Consultants. He previously served as the Vice President, production technology and digital mastering operations at Paramount Pictures. During his 24 year tenure at Paramount Pictures, Smith was responsible for artist approvals and technical quality for all electronic distribution. He received the Digital Pioneer Award at ShoWest 2006 and served on DCI for ten years. Smith is a member of the Academy of Motion Picture Arts and Sciences and recently served for 9 years on the Science and Technology Council. Prior to Paramount Pictures, he worked in various post production positions for Columbia Pictures, New World Pictures and the CBS Television Network. He is also an Associate Member of the American Society of Cinematographers and Lectures at various Universities. In his free time he can be found on the Napali coast in Kauai or creating glass art in Santa Barbara.

W. Thomas Wall is a retired Computer Systems Designer and Professional Photographer. He is the Chief Technology Officer at LightView.

A contribution received May 2017.